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Automatic Visual Inspection of Integrated Circuits Using an SEM

Ali Ertan Kayaalp, General Dynamics

In this thesis, we investigate the complex problem of designing an integrated circuit inspection system that will be used in controlling an automated semiconductor manufacturing facility. Such a system will have to be accurate, fast, and able to inspect integrated circuits with submicron features. To satisfy the accuracy requirements, we propose a system that integrates information supplied by multiple intelligent (virtual) sensors. Most of our work concentrates on the design of two scanning electron microscope (SEM) based intelligent sensors. One of them extracts 3-D IC surface topography information using computer stereo vision techniques and the other identifies shape defects in IC patterns using the IC design file as the reference. Both of these problems are viewed as constrained contour matching problems. In stereo matching, we match feature contours extracted from the left and right stereo images, whereas in pattern shape inspection, we match pattern boundary contours extracted from the image and the IC design file. We present an optimization technique for solving the matching problem that results in both cases. This general approach simplifies the task of transforming the specifications of a physical problem into a computational form and results in a modular system. Based on several experiments, we achieve stereo matching error rates of less than 5%. To meet the speed requirements of the inspection system, we discuss the parallel implementation of our algorithms on readily available, multiple instruction multiple data (MIMD) processors. We show how these processors can efficiently solve not only low-level vision problems, but also higher level problems (formulated as global optimization problems).

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Active Multiple-View Object Recognition

Hwang-Soo Kim, Korea

To recognize objects in a scene, a single view is sufficient if the scene is relatively simple, consisting of easily recognizable objects, or if the image was taken from a good viewpoint. In other situations, when initial images are not sufficiently informative, a multiple-view approach should be employed.

The multiple images are acquired from those selected viewpoints which will reveal some new objects or new aspects of the same object to help recognition, rather than

from random viewpoints, since more images are needed for recognition if viewpoints are selected randomly; and analyzing more images would be costly. This process will be called *active vision* since it actively moves to selected viewpoints and acquires more informative images to accomplish the vision task. Active vision has received little attention in vision research despite its importance.

The multiple-view approach needs a single-view object recognition as a subprocess which recognizes clearly visible and recognizable objects in each image. The single-view object recognition process analyzes each image frame to supply the information on recognizability of an object, and the possible identities and poses of the object if not recognizable. The multiple-view object recognition process accumulates this information in an accumulator which functions as an environment model and is used in selecting viewpoints.

At the end of each frame, if any object is still unrecognized, then a hypothesis is selected from the accumulated information and a new viewpoint is selected based on the hypothesis. The viewpoint is selected such that it shows features of the hypothesized object clearly. Another image frame is acquired from this new viewpoint. The process continues until all objects are recognized.

Two viewpoint selection algorithms, direct-down and vector-sum algorithms, are developed. The power of the active multiple-view vision is demonstrated using synthetic images of polyhedral objects. We obtained views which show features of objects clearly using the viewpoint selection algorithms.

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Automatic Generation of Morphological Set Recognition Algorithms

Robert Carl Vogt III, Environmental Research Institute of Michigan

A system for automatically generating simple morphological set-recognition algorithms is described and implemented. The program accepts a group of binary or gray level images, along with two "truth" masks for each, indicating the pixels to be accepted and those to be rejected. It then searches an image operator/parameter space for possible solutions, using domain knowledge about the uses and effects of individual operators to reduce the search. Solutions are presented in terms of an image algebraic target language. Currently, the system can solve problems which have perfect or nearly perfect solutions in a few operator steps from a repertoire of several thousand operator/parameter combinations. The system supports roughly a dozen different operator groups drawn primarily from mathematical morphology (e.g., erosion, dilation, opening, closing, etc.), covering such image characteristics as absolute position, distance from the foreground or background, size class of pixels, and width, roughness, and length of connected particles and holes. The system is shown to be equivalent to an exhaustive search, in that it cannot miss any solutions which fall within its defined scope, yet efficient, in that it accomplishes its task significantly faster than would an exhaustive search technique. Research into this area offers the potential to enhance our formal understanding of image operators and when to use them, to provide better, more powerful tools for testing and evaluation of image algorithms by algorithm developers, and to partially or even completely automate some algorithm development tasks via systems that can intelligently manage the search and testing process. Building such systems also provides a way to model the algorithm development process as carried out by humans, which can improve our understanding of how to make such efforts more efficient.

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Polynomial Methods for Structure from Motion

Charles Paul Jerian, SUN Microsystems

There have been many attempts to solve the SFM problem, yet few practical solutions. Previous work has used either linearizations that ignore vital constraints or nonlinear equations with multiple solutions, where the existence of multiple solutions has been ignored.

First, we classify and analyze many existing methods and find that they do not work well in the presence of noise, or without a good initial estimate. Then, we propose new polynomial systems solutions for both orthographic and perspective projection that work better than existing methods in the presence of noise. Finally, we examine the effect of such factors as the number of frames and the axis and angle of rotation on the ability to recover structure. We found that additional frames are of no value and that large amounts of rotation resulting in disparate views are very helpful for accurate structure recovery.

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